by Nicol Morton

Linking land and sea: Towards global reconstructions of the Jurassic world

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The Jurassic is traditionally famous for shallow marine sediments that are often very fossiliferous, notably in Europe, where the standard chronostratigraphic subdivisions were established and defined. However, widespread marginal and non-marine Jurassic sediments are also known, and are of great importance for the well-preserved terrestrial biotas they contain, as well as for their hydrocarbon and coal reserves. IGCP Project 506 is directed towards finding means of correlation between marine and non-marine Jurassic rocks, as a foundation for a better understanding of the evolution of the Earth during the Jurassic Period.

Introduction

The traditional understanding of Jurassic rocks is that they are predominantly shallow-marine sediments, which are often highly fossiliferous. This is especially the case in Europe, where many of the basic principles of stratigraphical geology were first worked out. The rocks have been investigated for over 200 years, resulting in a database which is better than those for most other strata, though is still being improved by continued research.

The classical European sections in the Jurassic, in Britain, France and Germany and elsewhere, provide the basis for the standard chronostratigraphic subdivisions of the Jurassic System. These are now already defined, or will be soon, by Global Stratotype Sections and Points (GSSPs) in accordance with the requirements of the International Commission on Stratigraphy of IUGS (Remane et al., 1996). Thus, in his classic monumental review of the Jurassic of the world, W.J. Arkell (1956) was able to summarise the then known Jurassic of nearly all parts of the world by reference to the (European) Standard Stages, and often (ammonite) Zones.

There are some interesting gaps in the geographical coverage of Arkell's book (1956)—areas where nothing was known about the occurrence of Jurassic rocks. Examples include the offshore areas of the North-East Atlantic, including the North Sea where Jurassic rocks are of great importance as hydrocarbon source rocks and reservoirs. More widespread geographically are the Jurassic rocks of eastern Asiatic Russia and China, where there are, in addition to hydrocarbons, significant coal reserves. In recent years well-preserved and important terrestrial biotas, including dinosaurs, have been discovered in several continents. A major problem has been in establishing the geological ages of these biotas, because of problems of correlation with the standard chronostratigraphical subdivisions of the Jurassic that are defined in marine successions. A classic example is the famous Jehol Biota (Chang et al., 2003), the age of which has been variously interpreted as Middle Jurassic, late Jurassic or Early Cretaceous. There are many other examples of such uncertainties.

Without reliable correlations between the marine and non-marine rocks formed during the Jurassic Period, our understanding of the evolution of the Jurassic world during this time of important tectonic, palaeogeographical and palaeobiological changes will be

greatly hampered. It was to work towards overcoming these problems that IGCP Project 506 was proposed.

Chronostratigraphy of marine successions

Jurassic stratigraphers are fortunate in having available a group of invertebrates that is one of the best biochronological indicators available, the ammonites. These shelled cephalopod molluscs were Nektonic or nekto-benthic, and are, therefore, common (even abundant) in many different facies of marine sedimentary rocks. They evolved rapidly and are (relatively) easy to identify. They have been studied for over 200 years so that they provide a reliable foundation for the biochronological subdivision of the Jurassic, into the Global Standard Stages and Zones (Morton, 2006). These are based on the successions in the classical areas of Europe. Arkell (1956) was able to use the Stages and (usually) the Zones as the chronostratigraphical framework for his review of the Jurassic of the world. For the most part this still applies at Stage level, but there has been more recently a tendency to name Regional Standard Zones rather than impose a European standard that is less suitable. The correlations with the European standard are also given as precisely as possible. As an example of this application of Regional Ammonite Zones in the circum-Pacific region see von Hillebrandt et al. (1992).

The relative precisions of correlations based on ammonites are remarkably high (Callomon, 2001), with estimated mean durations for Jurassic subdivisions of 4.92 Ma for each of the stages, 712 ka for the 76 zones, 338 ka for the (variable) c.160 subzones, and perhaps 120 ka where ammonite horizons have been established. Where good ammonite faunas are available it is possible to make correlations and comparisons at an extremely high level of resolution. This is not relevant where ammonites do not occur.

Other marine fossil groups are used for correlation and there are zonal schemes based on some of these. However, most are calibrated against the ammonite zones and rarely give comparable levels of precision.

Unfortunately, the durations of the Jurassic stages and zones in numerical terms (Ma) are very much less well constrained; most stage boundaries have uncertainties of ± 1.0 to 4.0 Ma (Gradstein et al., 2004) which compare unfavourably with the estimates given above. It may be difficult to make a confident correlation with the standard chronostratigraphic units for even a well-constrained radiometric date.

Possible means of marine to non-marine correlation

Given that ammonites, or other fossils of marine organisms, do not occur in non-marine sediments, other means of correlation must be sought. These can be simplified into biostratigraphical, chemostratigraphical and physico-stratigraphical methods. Only a few examples are mentioned here in illustration of possible investigations.

Biostratigraphy

Ostracods: A few groups of organisms represented reasonably well in the fossil record, including ostracods, are euryhaline, that is the representatives of the group range from fully marine to brackish- or fresh-water, though not normally the same taxa. Studies of overlapping ranges are required.

Sharks: Modern sharks range from marine through marginal environments, and some species venture into fluvial environments. Although skeletons are rare, shark teeth are distinctive in morphology and robust in composition so that they can be recovered from sediments by processing large samples (Underwood, 2004). Their potential for biostratigraphy and correlation remains to be investigated.

Land plants: Organisms that live in terrestrial environments can be transported, post-mortem, into marine environments and fossilised in marine sediments. One example (others could be cited) is of drifted land plants which were found associated with ammonites and other marine fossils in the Aalenian and lower Bajocian in NW Scotland (Bateman et al., 2000), enabling precise relative dating of the plants. The plants were mainly fragments but early diagenetic permineralisation resulted in superb preservation of cellular structures. Study of the plants yielded valuable palaeoecological and palaeoclimatic information, but no morphological changes could be detected over the limited stratigraphical interval studied and stratigraphical ranges remain to be established.

Palynology: Spores and pollen are also frequently transported from their normal terrestrial environment and deposited in marine sediments. Numerous examples could be cited but only one topical example is cited here. Recent investigations on the newly-discovered Triassic-Jurassic boundary section at Kuhjoch (Karwendel Mountains, Austria) by von Hillebrandt, Krystyn & Kuerschner (2007) included documentation of the marine fossils, including ammonites (the section is a candidate for GSSP of the base of the Jurassic), and of palynomorphs (by W.M. Kuerschner). The first occurrence of the pollen *Cerebropollenites thiergartii* was found to coincide with the first appearance of the ammonite *Psiloceras cf. spelae*, thus providing a marker for the base of the Jurassic which bridges the barrier from the marine to the non-marine realm.

Chemostratigraphy

Carbon isotopes: Variations in the percentages of the stable isotopes of carbon ^{12}C and ^{13}C provide one signal of environmental change which has potential to be identified in both marine and non-marine environments (Newton and Bottrell, 2007). Distinctive carbon isotope variations (sharp decreases of ^{13}C percentages) have been identified at/near (depending on eventual definition) the Triassic/Jurassic boundary (McRoberts et al., 2007) and in the lower Toarcian (Hesselbo et al., 2000). Close sampling control and some supporting evidence are necessary to ensure correlations, but the potential for correlation between marine and non-marine is clear (and proposed for the Toarcian example).

Magnetostratigraphy

The palaeomagnetic signal record should be identifiable in both marine and non-marine successions. The problem remains that it is a binary signal that requires independent calibration for its use in correlation.

Sequence Stratigraphy

Pienkowski (2006) has discussed the use of sequence stratigraphy in correlation across the diachronous non-marine to marine environmental transitions in the uppermost Triassic and lowermost Jurassic. This need not be discussed here.

Cyclostratigraphy

Orbitally driven Milankovic cyclicity has been proposed as a cause of cyclicity in sedimentary successions (Hinnov and Park, 1999) and has been interpreted for Mesozoic terrestrial lake basin sediments by Olsen (1986) and for the marginal to marine Triassic-Jurassic boundary succession in Northern Ireland by Simms and Jeram (2007). However, the potential for marine to non-marine correlations using this technique does seem to depend on the cyclicity being tied to independently derived correlations.

Radiometric dating

An obvious means of correlations between marine and non-marine successions in the Jurassic would be the use of radiometric dates to establish age correspondences. There are presently two main impediments to the general application of radiometric dates. The first is their rarity in the Jurassic, especially in situations that would enable precise correlation with the standard ("Global") Chronostratigraphical and Time Scales. The second concerns their (chrono-)stratigraphical significance; it is not always clear what event is recorded in the geological history of a rock. The precision of correlation will also be limited by the analytical error.

Conclusions

There appear to be several possibilities for achieving correlations between marine and non-marine Jurassic sequences. My impression is that an integrated approach involving application of as many as possible to each case will be required. It will probably not be best to try to correlate the Standard Stage boundaries, but rather to concentrate on potentially correlatable levels. For example, the early Toarcian oceanic anoxic event should be investigated as widely as possible.

For biostratigraphical applications the first essential is a sound taxonomy, ideally with several individuals independently investigating the same sample sets and comparing results. This way the data become reliable.

Acknowledgements

This is a contribution to IGCP Project 506: Marine and non-marine Jurassic correlations.

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Hutchison 'Young Scientist' Fund

William Watt Hutchison, "Hutch" to his many friends around the world, was a Scots-born Canadian geologist who served Canada and the IUGS in myriad dynamic and creative ways. Most notably, he served as the IUGS Secretary General (1976–1980) at a pivotal time in its history, and as IUGS President (1984–1987). The same boundless energy, enthusiasm, skill in communications, and ability to foster teamwork that characterized his work with the IUGS also carried him to preeminent scientific administrative positions in the Canadian Government, where he served as Director General of the Geological Survey of Canada and as Assistant Deputy Minister of Earth Sciences. His distinguished career was terminated in 1987 by his untimely death at the age of 52, following a painful struggle with cancer.

One of Hutch's last wishes was to establish under IUGS auspices a memorial foundation intended to promote the professional growth of deserving, meritorious young scientists from around the world by supporting their participation in important IUGS-sponsored conferences. The first 3 beneficiaries of the **Hutchison "Young Scientist" Foundation** attended the 28th International Geological Congress (IGC) in Washington, D.C., in 1989.

Initially, earned interest on the funds available to the Hutchison Foundation were insufficient to sustain comparable grants every four years without seriously eroding the principal. For that reason, the IUGS made no grants from the Foundation for the 30th IGC (1996), preferring instead to strengthen the fund by allowing it to earn interest for a longer period of time and by appealing for donations from the international geologic community. Grants from the Foundation again supported deserving young scientists beginning with the 31st IGC (2000), and should continue for future Congresses. The IUGS would like to expand the resources of the Foundation to make it possible also to offer support to deserving young scientists to attend other important IUGS-sponsored scientific meetings. The **Hutchison "Young Scientist" Foundation** is a worthy cause that honors a fine, caring man and a distinguished, public-spirited scientist and administrator. The foundation also celebrates and promotes those things that gave Hutch the most professional satisfaction: geology, international scientific collaboration, and stimulating young minds.

The IUGS welcomes contributions to the **Hutchison "Young Scientist" Foundation**. Please send donations to:

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